RP 106 Wind Turbine Gear Oil Filtration Procedures

The following recommended practice (RP) is subject to the disclaimer at the front of this manual. It is important that users read the disclaimer before considering adoption of any portion of this recommended practice.

This recommended practice was prepared by a committee of the AWEA Operations and Maintenance (O&M) Committee.

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Purpose and Scope

The scope of "Wind Turbine Gear Oil Filtration Procedures" addresses full-flow gear oil filters installed in wind turbine gearboxes. Flushing filters and off-line (a.k.a. kidney loop) filters that may also be used with these gearboxes are defined but not discussed further in this recommended practice. Water and other types of contaminants are not discussed in this practice.

Introduction

Full-flow filters are used to protect gearbox mechanical components from particle contamination suspended in gear oil. The major sources and types of particle contamination, along with associated wear mechanisms, are compiled in Table A. (*See Table A*) The most contaminant sensitive gearbox components are bearings, followed by dynamic seals, pumps, and gears. One study by Timken established gear tooth wear debris as causing the greatest damage to rolling bearings[1]. In a second study, NASA found increases in rolling bearing life up to 6 times with increasing oil cleanliness maintained with highly efficient filters[2].

Table A: Damaging Contaminant Particles Found in Wind Turbine Gear Oil.

Sources/Ingression	Types	Wear Mechanisms
airborne mineral dusts	vents, ports, seals	sliding contact abrasion in gears, seals, pumps, retainers
metallic wear debris	gear tooth wear	rolling contact fatigue leading to pitting, spalling
manufacturing swarf: polishing/lapping grits, metallic chips	new installations, replacement parts	early failures of bearings, pumps, seals, gears
salt	marine sea spray followed by airborne ingression	corrosion

Full-Flow Gear Oil Filter Procedures

1. Target Particle Contamination Levels

In order to minimize damage to gearbox components, it is recommended that gear oil be maintained at or above specified levels of cleanliness. Quantities of particle contamination measured in oil samples are typically reported according to ISO 4406[3]. This format reports the number of particles per milliliter equal to or greater than a given size in micrometers (μm). Particles per milliliter greater than 3 sizes are reported:

1 ≥ 4 μm
2 ≥ 6 μm
3 ≥ 14 μm

The number of particles for each size range is reported as an ‘ISO Code’. For example, the number of particles in a particular sample of gear oil is reported as: ISO 19/17/15.

This translates to:

- 19: 2500-5000 particles/mL ≥ 4 μm in size
- 17: 640-1300 particles/mL ≥ 6 μm
- 15: 160-320 particles/mL ≥ 14 μm

1. Target Particle Contamination Levels
(continued)

An increase of one ISO Code equates to an increase in particle contamination by a factor of 2. As a second example, an oil sample with an ISO Code of 20/18/16 has in each size range two times more particles than the previous example. Maximum particle contamination levels are specified by gearbox or turbine manufacturer, or by in-house specification. Table 17 of *ANSI/AGMA/AWEA 6006-A03*[4], (*See Table B*), suggests a set of maximum allowable contamination levels for wind turbine gearboxes. Turbine or gearbox OEM, or in-house specifications, take precedence over this table.

Table B: Lubricant Cleanliness

Source of Oil Sample	**Required Cleanliness Per ISO 4406**
Oil added into gearbox at any location	- / 14 / 11
Bulk oil from gearbox after factory test at the gearbox manufacturer's facility	- / 15 / 12
Bulk oil from gearbox after having been in service 24 to 72 hours after commissioning of the WTGS (pressure fed systems only)	- / 15 / 12
Bulk oil from gearbox sampled per the operating and maintenance manual (pressure fed systems only) (See Step 6.7.)	- / 16 / 13

Particle contamination in operating systems may be monitored by two alternative approaches:

This translates to:

- Periodic oil samples are obtained from the gearbox then sent to a laboratory for analysis. This is the method currently used by a large majority of operators.
- An on-line particle counting unit mounted on the gearbox. This has the advantage of providing real-time data. Disadvantages are unit and installation costs and maintenance.

2. Selecting Full Flow Gear Oil Filters

2.1. Definitions

2.1.1. Full-flow filters receive the total flow of lubricant produced by the main lubrication system pump(s). All suspended particles in the oil reservoir are carried by the flowing gear oil into these filters. Depending on filter efficiency (filter rating), many to most damaging particles are removed from the gear oil by the full-flow filter before reaching loaded mechanical components, especially bearings and gears.

2.1.2. Off-line filtration systems are designed to operate independently of, or in addition to, the full flow filtration system. Off-line filtration may be used to supplement contaminant removal by full-flow filters, if deemed necessary to meet specified cleanliness levels.

2.1.3. Flushing filters are used to clean a gearbox during an oil change or after a system upset. These filters are temporarily plumbed into the gearbox lubricant system, and removed when the clean-up is completed. Flushing filter ratings should be as good as or greater than the full-flow filters installed on the gearbox.

2.2. Full-Flow Filter Ratings

The function of a full-flow filter is to remove damaging particles from the lubricant. For modern industrial filters, particle removal efficiency (a.k.a. filter efficiency) is reported as a ‘filter rating’. Examples are filters rated at 5 µm or 10 µm. For particles this size and larger the filter is extremely efficient, as determined and quantified by laboratory testing. As illustrated in Figure A, filter efficiency is determined by ISO 16889[5]. (*See Figure A*)

2.2.1. The procedure is performed under controlled laboratory conditions.

2.2.2. A slurry of test dust (finely powered silica sand) in oil is flowed into the filter.

2.2.3. The number of particles entering and leaving the filter are sized and quantified throughout the test using electronic particle counters.

2.2.4. Filter ratings are reported as beta ratios:
ß10(C) = Number Particles Upstream ≥ X µm ÷ Number Particles Downstream ≥ X µm.

2.2.5. For example, a filter rated at 10 µm has ß10(C) ≥ 1000.

2.2. Full-Flow Filter Ratings
(continued)

2.2.6. Not all filters are equal. For example, a filter rated at 5 µm is 20 to 50 times more efficient at removing particles than a 10 µm filter, which in turn is 20 to 50 times more efficient than a filter rated at 20 µm.

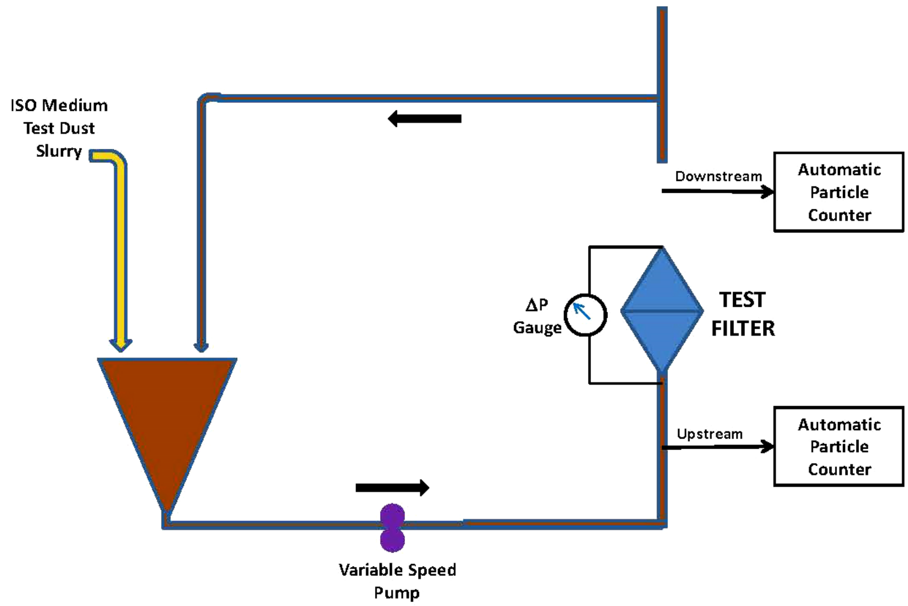

Figure A: Multipass Test Per ISO 16899

2.3. Proper Filter Performance Parameters

Several additional parameters are required to ensure proper filter performance in a gearbox:

2.3.1. Differential Pressure (ΔP)

Filters present restrictions to flow. As gear oil flows through the filter, differential pressure (ΔP) develops across the filter. Differential pressure increases with increasing flow rate and oil viscosity. Cold gear oil flowing through a filter, such as during a system cold-start, often produces the greatest differential pressure experienced by full-flow filters. A maximum differential pressure may be specified by the gearbox or turbine OEM for unused filters at specific flow rates, oil types, and temperatures.

2.3. Proper Filter Performance Parameters
(continued)

2.3.2 Compatibility and Integrity

The full-flow filter must be able to maintain integrity and withstand maximum differential pressure, including during cold-start, after contacting gear oil at highest system temperature. For additional information, see ISO 2941, *"Verification of Collapse Burst Pressure Rating"*, and ISO 2943, *"Filter Elements - Verification of Material Compatibility with Fluids"*.

2.3.3. Filter Service Life

As filters capture and retain particles, flow restriction and differential pressure increases. Full-flow filters are changed at or before a maximum differential pressure is reached. This ΔP value is specified by the gearbox or turbine manufacturer. The time interval between installation and removal is termed the filter service life. The ISO 16889 Multipass Test measures dirt holding capacity of silica sand under controlled conditions. However, because different types of contaminants load filters during field operation, this test method may not accurately predict the service life of full-flow filters in wind turbine gearboxes. It is recommended service life be established by field experience and evaluations.

2.4. Selecting a Full-Flow Filter

The full-flow filter should meet or exceed the specifications of the gearbox and/or turbine manufacturer. The filter rating should be sufficient to meet or exceed target cleanliness levels under real-world operating conditions. For concerns with possible removal of additives, confer with the oil supplier.

3. Changing Spent Gear Oil Filters

Two strategies are used for changing spent full-flow filters. The strategy used at a specific site may be specified by the gearbox or turbine manufacture, or by an in-house specification.

3.1. On-Time

This is the strategy used by the majority of wind turbine operators. Full-flow filters are changed at a convenient service interval. Currently, the most common service interval for land-based turbines is 6 months. Because filters are expected to last a minimum of 6 months, many are changed before dirt holding capacity has been depleted.

3. Changing Spent Gear Oil Filters
(continued)

3.2. On-Condition

Full-flow filters are changed when a differential pressure indicator signals a pre-determined value of ΔP. This change-out ΔP is set below the differential pressure that activates the by-pass valve, avoiding unfiltered lubricant passing into the gearbox. Because the maximum dirt-holding capacity of the filter is used, this method tends to increase filter change-out interval length. However, tower climbs at irregular intervals to change these filters may be inconvenient and/or un-economical.

4. Filter Change-Out Check List

______ **1.** **Down Tower**
Inspect new filter. There should be no damage from handling/shipping.

______ **2.** **Bring Up Tower**
Plastic waste bag for used filter.
If changing spin-on filter, bring belt wrench.
2 gallons of pre-filtered make-up gear oil.

NOTE: The rating of the filter used for pre-filtering the gear oil should be at least as fine as the filter installed in the gearbox.

______ **3.** **If Changing a Cartridge Filter**
Remove cover from housing.
Partially remove used filter and let drain for several minutes.
Completely remove used filter and place in plastic waste bag.
Install new filter into housing.
Secure cover onto housing and tighten fittings.
Top up oil as needed.

______ **4.** **If Changing a Spin-On Filter**
Remove old spin-on. May need belt wrench.
Place old spin-on filter into plastic waste bag.
Spin new element onto filter head and tighten.
Top up oil as needed.

______ **5.** **When Back Down Tower**
Discard used element according to company policy.

Summary

By protecting contaminant sensitive components from harmful particles, full-flow gear oil filters are indispensable for achieving acceptable uptime and life of wind turbine gearboxes, as well as for reducing maintenance costs. The full-flow filter installed on the gearbox should meet or exceed specifications. Specifications include, but are not limited to: filter rating (particle size where ß X(C) ≥ 1000), differential pressure (ΔP), compatibility, and integrity. The filter should also provide an acceptable service life based on the needs of the site. A check-list is included to aid the proper change-out procedure when replacing spent filters with new filters.

References

[1] E. V. Zaretsky and W. M. Needelman, “Recalibrated Equations for Determining Effect of Oil Filtration on Roller Bearing Life,” in *STLE Proceedings 64th Annual Meeting*, Orlando, 2009.
[2] M. Kotzalis and W. M. Needelman, “Minimizing Oil Contamination and Using Debris Resistant Bearings to Enhance Wind Turbine Gearbox Performance,” in *Proceedings International Joint Tribology Conference*, Memphis, 2009.
[3] *Hydraulic Fluid Power -- Fluids -- Method for Coding the Level of Contamination by Solid Particles*, ISO 4406:1999, 1999.
[4] *Design and Specification of Gearboxes for Wind Turbines*, ANSI/AGMA/AWEA 6006-A03 (R2010), 2010.
[5] *Hydraulic Fluid Power Filters -- Multi-pass Method for Evaluating Filtration Performance of a Filter Element*, ISO 16889:1999, 1999.

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